

HEAT TREATMENT
OF HIGH SPEED TOOL STEELS

BY

H. PERLSTEIN
D. B. LESSER

ARMOUR INSTITUTE OF TECHNOLOGY

1914

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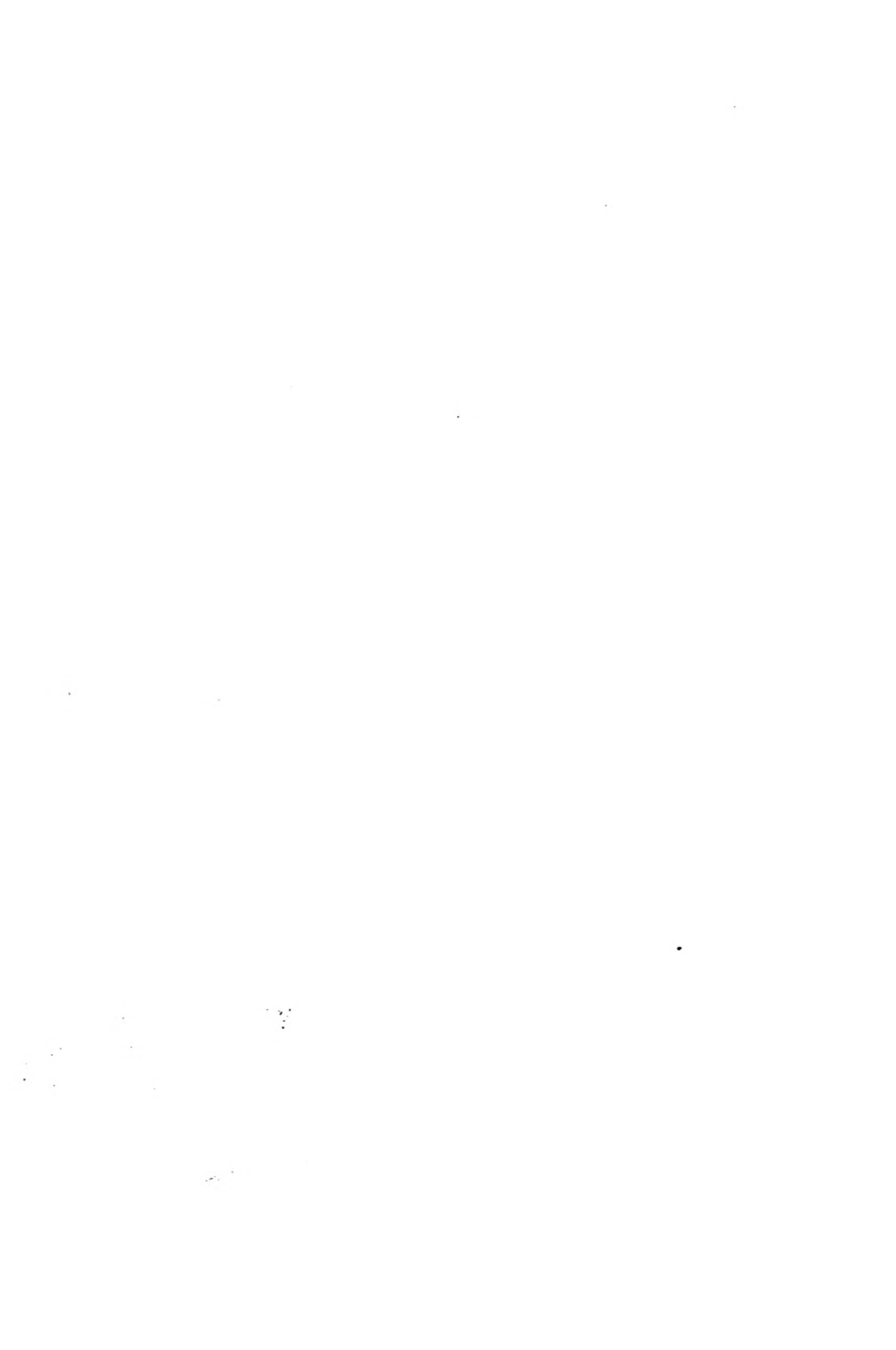
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Perlstein, H.

Heat treatment of chrome
tungsten high speed tool

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1. The first group of people who are affected by this disease are the elderly. As people age, their immune system becomes weaker, making them more susceptible to various infections and diseases. This is why older adults are often the first to be affected by illnesses like pneumonia or the flu.

A Thesis
Presented by
Harris Perlstein
and
David Barnes Lesser
to the
President and Faculty
of
Armour Institute of Technology
for the degree of
Bachelor of Science
Having Completed the Prescribed
Course in Chemical Engineering
May 28, 1914.

Approved by

A. M. McCormack
Professor of Chemical Engineering

H. M. Raymond
Dean of Engineering Studies

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Dean of Cultural Studies

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Heat Treatment of
Chrome Tungsten High Speed
Tool Steels.

By
Harris Perlstein
and
David Barnes Lesser.

1944.14

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plates.

The exact conditions of heat treatment which will insure the maximum of cutting strength and life to a high speed tool are a matter of much interest to the user of the tool and the manufacturer of the tool steel. In spite of the liveness of the topic, so far as is known to the authors little accurate information is to be had concerning it. Experience with the various steels on the market, together with some few researches has pointed out certain temperature ranges for preheating which, coupled with certain methods of quenching, produce tools that work satisfactorily in a lathe. It is to be remembered, however, that a tool may work satisfactorily from the operator's viewpoint and yet be producing, per dollar input to the lathe, less than it could be made to produce by scientific heat treatment. Careful investigation should furnish data for determining what heat treatment is best in any particular case; but it is this data which is available for very few of the tool steels used in this country.

The plan of study originally outlined by the authors was briefly as follows:

Certain of the better known high speed steels were to be worked with in an endeavor to learn what heat treatment would give best results in each case. Specimens of these steels were to be treated at various temperatures and quenched, and the treated specimens studied and compared by means of microphotography and cutting tests in

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[illegible]

a lathe. Analyses of the steels used were to be made to learn the present practice of high speed steel manufacturers, and in the hope that some clew of correlation between chemical composition and behavior of the treated steels might be developed.

When work on the subject was begun it was decided that the mode of quenching to be used would be by cooling in an air blast, since this corresponds to most commercial practice.

In performing the analytical work difficulties were encountered which upset the tentative time schedule laid out at the start. It was found necessary to narrow the limits of the further work and the cutting tests planned on were therefore abandoned.

The work actually accomplished consisted in analysing, heat treating and obtaining microphotographs of specimens of the following chrome tungsten high speed tool steels:

Brand	Manufacturer or Dealer	Price Dollars per pound
Rekord Superior	Kent & Simpson	.95
Roldi	R. A. Frasse & Co.	1.00
Blue Chip	Frith-Sterling Steel Co.	.75
Novo	H. Boker	---
Arc (Jessops)	Crerar Adams & Co.	.75
Bethlehem	L. I. Nyerson	.60

The authors wish to express appreciation for helpful supervision of Professor H. McCormack and the suggestions of Dr. C. A. Tibbals, and Mr. H. B. Pulsifer.

Chemical Analysis.

Sampling.

Samples for analysis were obtained by drilling the annealed high speed tool steels with a tempered carbon steel twist drill. The piece to be drilled was surfaced on the grindstone until free of oxide and paint and the drilling was then accomplished without the use of lubricant of any kind.

All the steels with the exception of Record were received from the manufacturer or dealer in annealed bars. Attempts to anneal pieces of Rekord by heating white hot in a forge and cooling in a lime box, and by heating at various temperatures from 800° C. to 1200° C. in a muffle and allowing to cool in the muffle failed. Success was finally had by packing the steel in lime in an iron bomb, packing this in lime within a second iron bomb, heating to about 1200° C. and allowing the whole to cool off with the furnace.

Methods.

Below are given the analytical methods used, together with comments on difficulties encountered.

Silica.

A two gram sample is decomposed with thirty cc of aqua regia, taken dry on the hot plate and baked for one hour at 110° C. The baked mass is taken up in hydrochloric acid and the insoluble matter filtered off, and washed free from iron with warm dilute hydrochloric (1:2). The tungstic and

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silicic acids remaining on the paper are washed twice with warm water and the tungstic acid dissolved from the paper with warm concentrated ammonia. The paper and residue are ignited in a platinum crucible and weighed. Ten cc of hydrofluoric acid and two drops of sulphuric acid are added and the ignited material is evaporated dry on the hot plate, reignited and reweighed. The loss in weight is recorded as silica.

It may be objected that the treatment with ammonia dissolves some silica in addition to the tungstic acid, but the thorough baking and relatively small quantity of silica present in the samples worked with is believed to obviate this criticism.

Tungsten.

One half gram of the sample is decomposed on the hot plate with 20 cc of aqua regia and evaporation continued until the material is just moist. Five cc of nitric acid is added, evaporation on the hot plate continued to syrupy consistency and the beaker transferred to the water bath. The material is taken dry and dehydrated on the water bath for four to five hours. The mass is moistened with nitric acid and warmed on the water bath, enough water is added to dilute the nitric to about 1:3 and the residue is filtered off and washed free of iron with nitric acid (1:3). The filtrate and washings are set aside for use in determining chromium. The material on the filter paper is washed once or twice with hot water and the tungstic acid is then dissolved from the paper with warm ammonium hydroxide. The filtrate is caught in a tared platinum dish and evaporated almost

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dry on the sand bath. Nitric acid is added in slight excess and the evaporation continued to dryness. Subsequent ignition (preferably in a muffle) gives, by gain in weight, the tungstic oxide corresponding to the tungsten content of the steel.

The above method was decided on at the suggestion of Dr. C. A. Tibbals, after the method outlined below had been found to give low results.

Two grams of the sample was treated with aqua regia, the hydrochloric was replaced by nitric and the mass was baked on a hot plate. The baked material was taken up in nitric acid, the insoluble matter filtered off, washed free of iron and dissolved back into the original beaker with ammonium hydroxide. The solution was filtered (to get rid of silica) and the tungsten reprecipitated by acidifying with nitric acid. The precipitate was filtered off, ignited in platinum and weighed as tungstic oxide.

This method was tried out on B. S. chrome-tungsten steel number 31 and gave results several per cent low (approximately 7% low on a steel containing 19% of tungsten). The large error was due to difficulty in reprecipitating the tungstic acid from ammonia solution from a bulk of about 300 to 400 cc. (It was noted here that the precipitate was generally very white, indicating a high degree of hydration). By evaporating the ammonium filtrate almost dry on the water bath and then acidifying, far better

[illegible]

results were obtained by Dr. Tibbals in attempting to check the authors, but the filtrate after the acidification still contained a very appreciable quantity of tungsten, hence the method first given was adopted, the sample being cut from two grams to one half gram. The dehydration is carried out on the water bath rather than the hot plate in order that chromium, which is determined on the same sample be not rendered insoluble.

Chromium.

The filtrate from the tungstic and silicic acids is evaporated nearly dry, 20 cc of nitric acid and two grams of potassium chlorate are added and the solution boiled for ten minutes. Ten cc of nitric acid and one gram of potassium chlorate are added and the solution boiled again for ten minutes. The chromium is now completely oxidized to chromate. The solution is diluted somewhat, allowed to cool, and neutralized with ammonium hydroxide. The solution is filtered from the iron hydroxide and washed with warm water. The iron hydroxide is redissolved into the original beaker with warm hydrochloric acid (1:1), reprecipitated and washed, the reprecipitation and washing being continued until the iron precipitate is free of chromium. (Three to four precipitations are necessary), The filtrate and washings are acidified with acetic acid and lead acetate is added in excess. The precipitate is allowed to settle, filtered off and washed a few times with water and dissolved into the original beaker with hydrochloric acid, (1:1)

1. The first part of the paper is devoted to the

study of the properties of the function

defined by the integral

where Γ is the gamma function.

The function $\Gamma(x)$ is defined for all real

values of x and is

continuous and strictly increasing.

It is also known that

where $\psi(x)$ is the digamma function.

The function $\psi(x)$ is defined for all real

values of x and is

continuous and strictly increasing.

It is also known that

where $\zeta(x)$ is the Riemann zeta function.

The function $\zeta(x)$ is defined for all real

values of x and is

continuous and strictly increasing.

It is also known that

where $\eta(x)$ is the Dirichlet eta function.

The function $\eta(x)$ is defined for all real

values of x and is

continuous and strictly increasing.

It is also known that

where $\theta(x)$ is the theta function.

The function $\theta(x)$ is defined for all real

values of x and is

continuous and strictly increasing.

It is also known that

where $\phi(x)$ is the Euler phi function.

The function $\phi(x)$ is defined for all real

The solution is made up to about 400 cc, 20 cc of a fifteen per cent potassium iodide solution are added and titration is carried out against tenth or twentieth normal sodium thiosulphate solution with starch as the indicator.

The above method gave satisfactory results and was successfully checked by Dr. Tibbals on the one sample run by him simultaneously with his work on the tungsten.

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Manganese.

Manganese was determined by a slight modification of the Ford Williams method (B. S. circular no. 14).

Two grams of steel are decomposed with 30 cc of aqua regia and taken very nearly dry on the hot plate. Nitric acid is added and evaporation continued for a few cc to replace hydrochloric. Nitric acid (sp. gr. 1.2) is added and the insoluble matter filtered off and washed with nitric acid ~~xxxx~~ (1:3). The solution is evaporated to a few cc, 30 cc of concentrated nitric acid and 2 grams of potassium chlorate are added and it is boiled for ten minutes. Ten cc of nitric acid ~~and~~ one gram of potassium chlorate are added and the boiling is continued for ten minutes. The precipitate is filtered on asbestos, washed two or three times with strong nitric acid and then with water. The asbestos pad is transferred to a flask, shaken up with excess standard ferrous sulphate solution until the manganese dioxide is dissolved, and the excess of ferrous sulphate is titrated with potassium permanganate.

Nickel.

One gram of steel is dissolved in 25 cc of hydrochloric acid (sp. gr. 1.16). The solution is filtered and the residue washed with hot water. One gram of tartaric acid is added to the filtrate which is heated to 50° C. Sufficient dimethylglyoxime solution containing 2.5 grams in 220 cc of 98% alcohol, is

- Outline

added to precipitate the nickel present. (1% nickel requires twenty cc of the glyoxime solution). The solution is made very faintly alkaline with ammonia, the nickel coming down as a scarlet flocculent precipitate, which is filtered on a gooch crucible, washed well with hot water, dried at 100° C. and weighed, the weight obtained being converted to nickel by use of the factor .2031. (NiO8 H14 N4 O11 X.2031 equals Ni.)

Sulphur. (Evolution Method.)

Five grams of sample are dissolved in 60 cc of hydrochloric acid in a 500 cc erlenmeyer flask fitted with a dropping funnel and connected to an absorption flask containing a 100% solution of sodium hydroxide. The acid is run in quickly from the dropping funnel and the solution is boiled for fifteen minutes. The contents of the absorption flask are transferred to a beaker, diluted to 400 cc, cooled and made acid with hydrochloric. Titration of the hydrogen sulphide present is made against twentieth normal iodine solution.

Phosphorus.

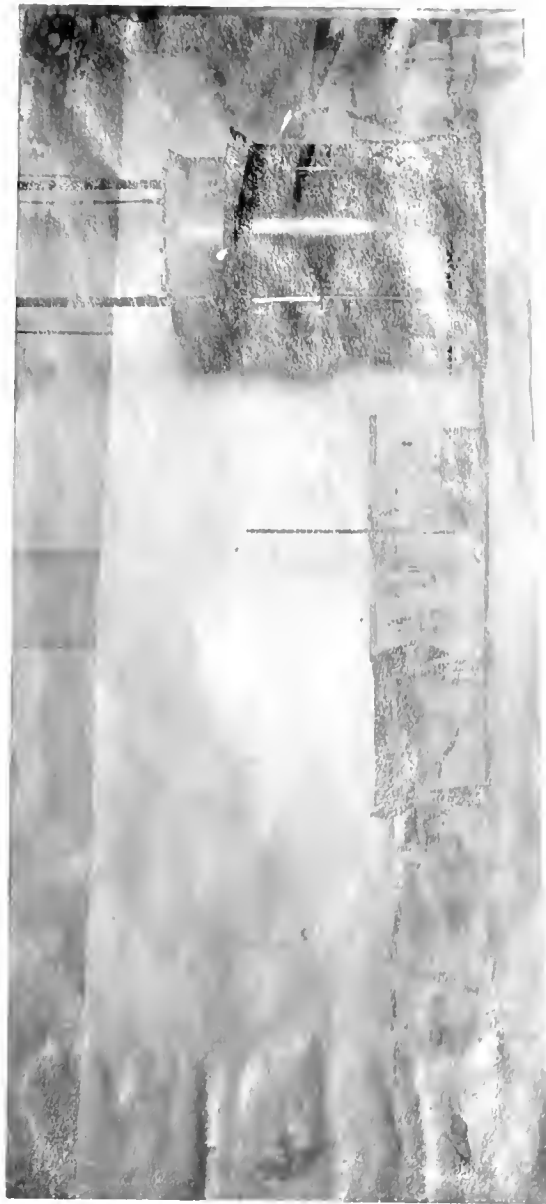
Phosphorus is determined alkalimetrically modifying the usual method according to the suggestions of Cain and Tucker (B. S. Technologic Paper No. 24) to avoid errors due to the presence of vanadium. Later it was found by qualitative tests that no vanadium was present in the steels worked with.

• 1111

Two grams of steel are dissolved in aqua regia and evaporated nearly dry, then taken up in five cc of nitric acid and run nearly dry again to replace hydrochloric. Nitric acid (sp. gr. 1.135) and ten cc of potassium permanganate solution (fifteen grams per l.) are added and the solution boiled. Sodium thiosulphate solution is added to dissolve manganese dioxide and the solution boiled and filtered. The filtrate is cooled to fifteen to twenty degrees C. and five cc of saturated ferrous sulphate solution and two or three drops of concentrated sulphur^{ous} acid are added. Forty cc of ammonium molybdate solution are added and the solution shaken for fifteen minutes at about 20° C. The precipitate is filtered and washed with 1% nitric acid, followed by 1% potassium nitrate solution, until the washings are no longer alkaline. The precipitate is then dissolved in excess standard sodium hydroxide solution and the excess hydroxide titrated back with standard nitric acid, using phenolphthalein as indicator. The sodium hydroxide is standardized against prepared ammonium phosphomolybdate.

Total Carbon
(Direct Combustion)

The electric combustion furnace shown in photograph number one is heated to above 950° C and oxygen is run through the apparatus to displace the air. The oxygen passes thru potassium hydroxide solution and over stick potassium hydroxide and then thru the furnace. The pro-



Photograph No.1

ducts of combustion pass thru two U tubes containing respectively, granulated zinc and calcium chloride and then thru a Geisler absorption bulb. The liquid and solid potassium hydroxide free the oxygen from carbon dioxide and water. The granulated zinc removes acid and sulphur fumes from the gasses of combustion which are dried by the calcium chloride and give up their carbon dioxide to the 50% potassium hydroxide solution in the Geisler bulb.

Two grams of drillings are placed in an alundum boat which is pushed quickly to the center of the silica tube of the furnace (the latter being ^{H.T.}), Oxygen is passing at the start at a fairly rapid rate and is controlled so that bubbles are continually passing thru the Geisler bulb during the run. The run is continued for 15 minutes. The increase in weight of the Geisler bulb, which has been previously weighed full of oxygen under atmospheric pressure, and which is again weighed under the same conditions, gives the weight of carbon dioxide corresponding to the carbon content of the sample.

Vanadium and molybdenum

(qualitative)

Qualitative tests for vanadium and molybdenum revealed the absence of these elements in all cases. The following method is adapted from that used by Millebrand to detect vanadium in rocks (Treadwell-Mall volume 1, page 489).

These of course are the first steps in the investigation of the case. It is necessary to determine the facts of the case and to identify the persons involved. The next step is to determine the motive for the crime. This is often the most difficult part of the investigation. Once the motive has been determined, the next step is to determine the means by which the crime was committed. This is often the easiest part of the investigation. The final step is to determine the person or persons who committed the crime. This is often the most difficult part of the investigation.

Two years of brilliant work have been done in the investigation of this case. It is now necessary to determine the facts of the case and to identify the persons involved. The next step is to determine the motive for the crime. This is often the most difficult part of the investigation. Once the motive has been determined, the next step is to determine the means by which the crime was committed. This is often the easiest part of the investigation. The final step is to determine the person or persons who committed the crime. This is often the most difficult part of the investigation.

Very truly yours,

J. Edgar Hoover

Enclosed for the Bureau are two copies of the report of the

Special Agent in Charge, New York, dated October 10, 1935.

Very truly yours,

J. Edgar Hoover

A sample of about 1 gram of the steel is decomposed with aqua regia, evaporated the small volume, diluted and made alkaline with ammonium hydroxide. The precipitate is filtered off, dried and fused in platinum or porcelain, with 10 grams of sodium carbonate and 2 grams of sodium nitrate. Fusion is leached with hot water and a little alcohol is added to reduce the manganate formed. The solution may contain phosphorous, chromium, vanadium, molybdenum and tungsten. It is nearly neutralized with nitric acid and evaporated nearly dry, taken up in water and filtered. A few cc of mercurous nitrate are added to the filtrate. Mercurous, phosphate, chromate, vanadate, molybdate and tungstate may precipitate. The solution is boiled and filtered and the precipitate is dried, ignited in platinum and fused with a little sodium carbonate. The fusion is leached with water and acidified with sulphuric acid. Hydrogen sulphide is passed. A brown precipitate soluble in ammonium sulphide, and reprecipitated by the addition of acids, is molybdenum trisulphide and proves the presence of molybdenum. Any precipitate caused by the hydrogen sulphide is filtered off and the excess hydrogen sulphide removed by boiling while a stream of carbon dioxide is passed thru the solution. The solution is evaporated to dryness and the excess of sulphuric acid is removed by heating in an air bath. The residue is

dissolved in the few cc of water and shaken with a few drops of hydrogen peroxide. The appearance of a brownish yellow color shows the presence of vanadium.

The first thing I noticed when I stepped out of the car
 was the cold air. It felt like a giant hand reaching out to
 grab me. I shivered and pulled my coat tighter around me.
 The snow was falling softly, creating a quiet blanket over
 everything. I took a deep breath, savoring the fresh, wintry
 air. It was a beautiful surprise.

ANALYTICAL RESULTS

	Rekord	Poldi	Bethlehem	Arc	Blue Chip	Novo
Silica	.18%	.17%	.28%	.13%	.18%	.46%
Manganese	.06	nil	.427	.065	.276	.290
Phosphorus	.01	.029	.038	.016	.052	.033
Tungsten	13.69	17.56	17.88	12.93	14.63	16.82
Chromium	2.35	2.33	2.54	2.90	2.48	1.50
Sulphur	.003	.009	.011	.025	.000	.015
Carbon	.56	.58	.52	.46	.70	.60
Nickel	nil	nil	nil	nil	nil	nil
Vanadium	nil	nil	nil	nil	nil	nil
Molybdenum	nil	nil	nil	nil	nil	nil

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6x 1

HEAT TREATMENT

Specimens

The steels were cut into lengths of five inches and numbered by a steel punch (see guide in appendix) to furnish the specimens for heat treatment.

Apparatus

An electric muffle furnace was available which answered the requirements of uniform temperature throughout the heating space and easy temperature control by the apparatus. This was used for the heat treatment. It was a Hoskins electric furnace type F. C. shown in photograph No. 2. This furnace was set well up from the floor and well heat insulated. The heating occurs from two sides and the top. The control switch board is shown a short distance back from the furnace.

It has been mentioned that cooling in an air blast was decided on as the mode of quenching to be employed. Pipe was run out from an air line to about three feet in front of the furnace, then down to the floor, and finally about 20 inches of 3-inch pipe was connected up vertically to serve as a cooling chamber. The arrangement is shown in photograph No. 3, which also shows how it was placed relative to the furnace. As the air entered the cooling chamber from the bottom thru a half-inch pipe it was not thought advisable to allow the specimen to rest on the bottom of the cooling chamber. Such a course would probably have

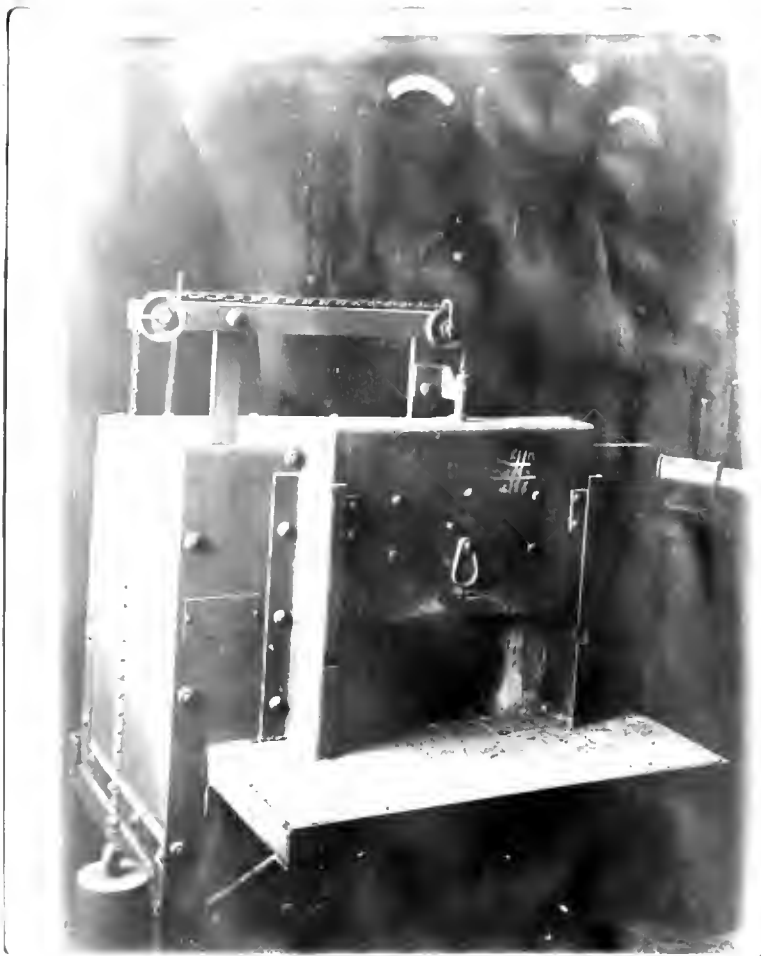


Photo-
graph
No.2



Photograph No.3



1.

produced unequal cooling due to the air jet not expanding immediately to fill the 3-in. pipe. A basket of wire gauze was therefore hung inside the pipe to arrest the specimen about 8 inches from the bottom.

Temperatures were measured with a Keiser & Schmidt (Berlin) platinum rhodium couple pyrometer, with bare knuckle. The pyrometer ends were put thru the back wall of the furnace projecting about halfway into the muffle space.

Method.

A temperature range of 900°C. to 1300°C. was decided on as embracing all the possible desirable temperatures. Specimens of each of the steels were therefore treated at 920°C. , 980°C. , 1040°C. , 1100°C. , 1160°C. , 1210°C. , and 1280°C.

Twelve specimens were placed on the floor of the muffle at once and as the temperature rose to the first desired point it was held there for 10 minutes, then the air blast was turned on and one specimen of each steel was quickly seized and dropped into the cooling chamber. The temperature was then raised to the next designated point and held there the same length of time prior to quenching as before. The procedure was repeated until all these steels had been treated at all the designated temperatures.

The ends of the heat treated specimens not

touched by the tongs were broken off at lengths of about one and a half to two and a half inches and these lengths were set aside for the metallographic work.

The atmosphere of the muffle was approximately neutral, because of the carbon lining, so that excessive oxidation of the specimens did not occur. This fact and the precautions observed are believed to have rendered the procedure of heat treatment described above free from material objection.

Metallography

The heat treated specimens including pieces of each of the steels in the annealed condition, were polished, etched, and photographed under a fairly high magnification.

Polishing

The polishing apparatus used was a Sauver vertical outfit. All polishing on the Sauver outfit is done on the flat side of plates mounted on a horizontal shaft. The plates include a grindstone and cast iron plates on which may be stretched canvass or soft buffing cloth.

The specimens were ground to a flat surface on the grindstone, or, in some cases, on a piece of emery cloth fastened to a flat plate in a high speed lathe. The flat surface was then finished, in turn, on wet emery paste, on canvass, wet tripoli paste on canvass and rouge on buffing cloth. The polishing was carried out until no scratches

were visible under 500 diameter magnification.

Etching.

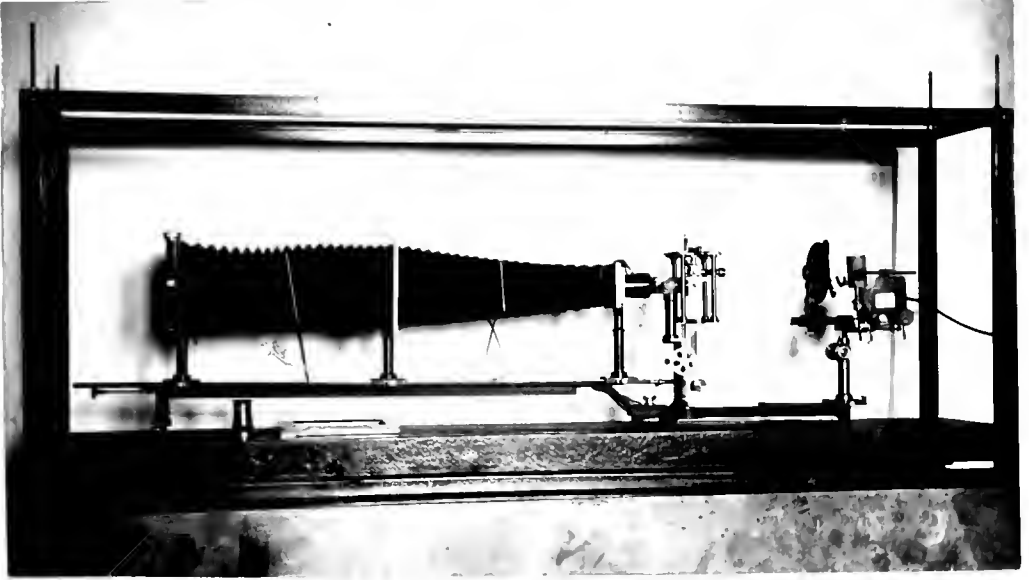
The following methods of etching were tried on the high speed steel.

Timed immersions from five to ten minutes in a 2% solution of picric acid and 95% alcohol, followed by quick washing and drying.

Timed immersions from five to ten minutes in the same picric acid solution followed by one second immersion in 10% nitric acid in water, followed by quick washing and drying.

Immersions of two to fifteen seconds in concentrated sulphurous acid followed by quick washings under running water dipping in alcohol and drying.

The picric acid etching gave fair results, but the sulphurous acid method was far shorter and equally satisfactory. The etching method adopted consisted in dipping the specimen in sulphurous acid, washing in running water, dipping in alcohol and drying with soft cotton. The specimen was then examined under the magnification to be used later in photographing and if more etching seemed desirable, a second or a third short treatment with sulphurous acid was employed. When the surface oxidized badly as a result of the etching, the oxide film was removed by rubbing on electro-silicon on a chamolite skin.



Photograph No.4



Microphotography.

A large metallurgical camera manufactured by C. Leitz, of Wetzlar, was available for the photographic work. Photograph No. 4 shows this camera, which includes an arc light, object stage, microscope and camera bellows, placed on a bed which is slung on springs in such a manner that any slight motion communicated to the apparatus does not disturb the relative position of the parts. An equipment of lenses allows a great variety of work with this camera. Its operation requires close familiarity with the various adjustments, as these are many and must be correct to obtain good results.

All the photographs were taken at a magnification of 500 diameters. The etched specimen was placed on the object stage, brought into sharp focus, and exposed for two and a quarter to two and a half minutes (depending on the surface) with a small opening in the diaphragm regulating the light supplied and a green glass screen interposed as a ray filter.

Five inch by seven inch photographic plates (Imperial S. S., supplied by Gernert) were used. These were developed with metol solution and prints were taken on hard finish special contrasty paper.

The prints contained are included in the following pages.



Poldi

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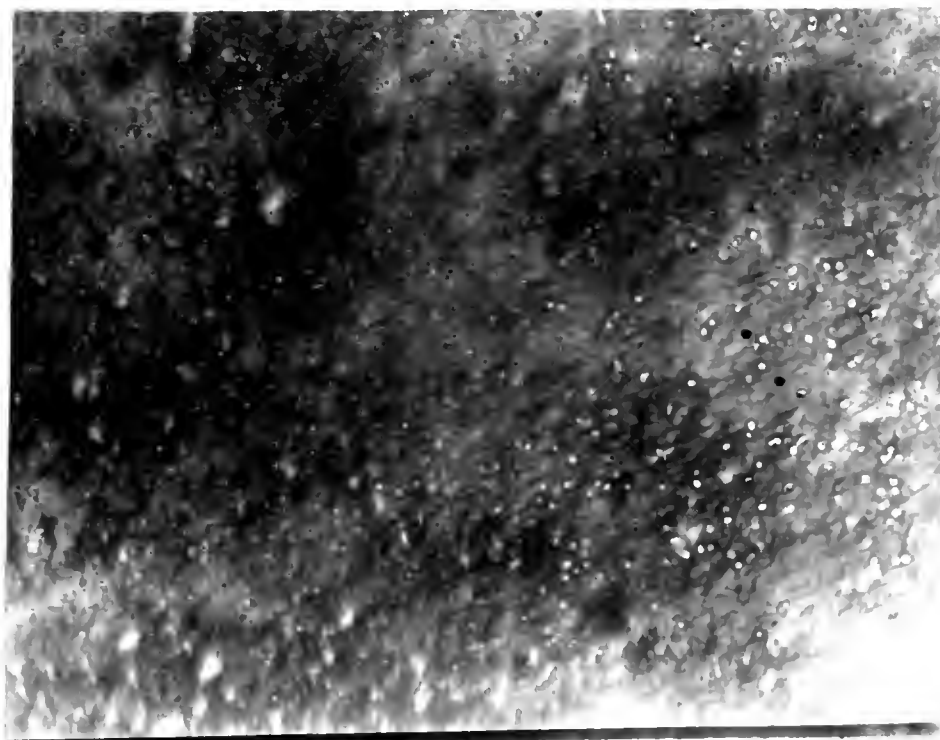
Annealed



Poldi

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Treated at 9200C



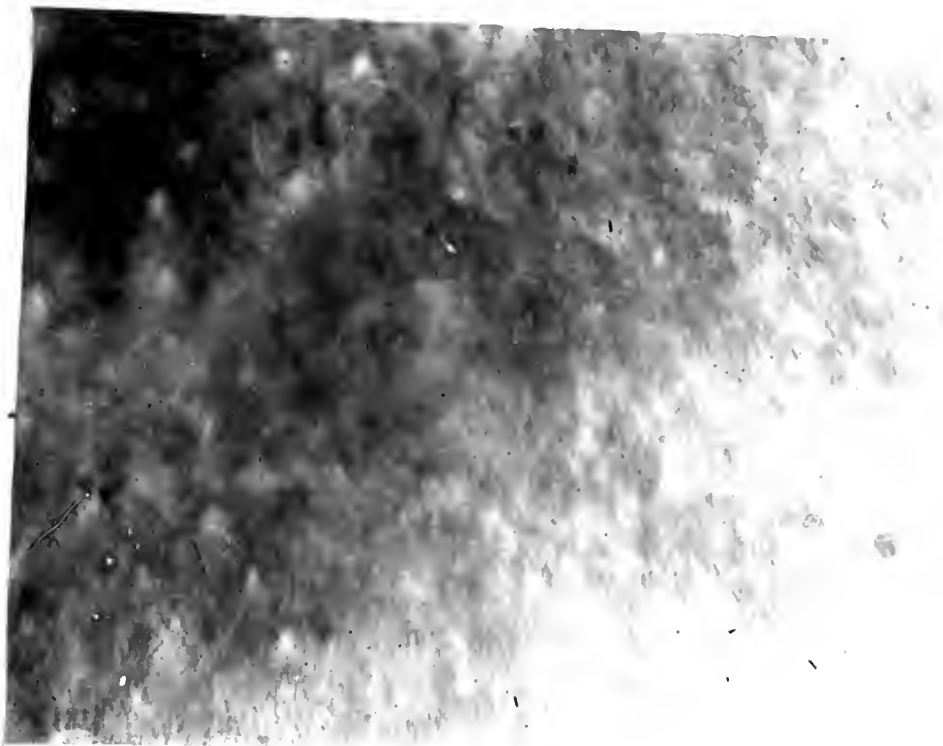
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2000-01-01 -- 2000-01-01

Poldi

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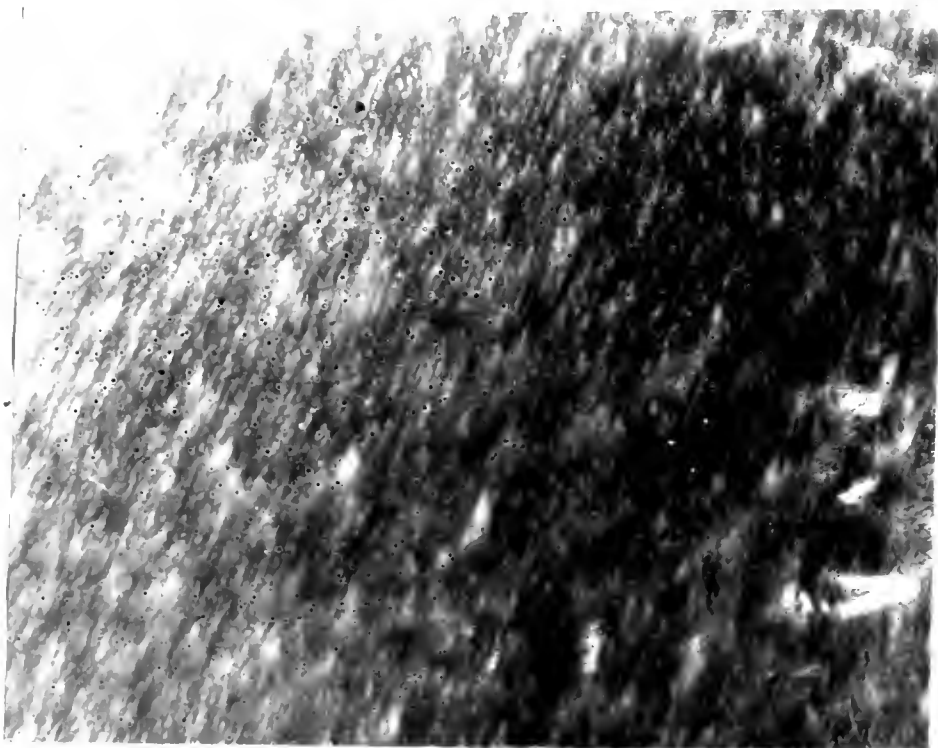
Treated at 980°C



Poldi

--

Treated at 1040°C



Director of State

1000

Director of State

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Poldi

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Treated at 1100°C



1

Poldi

Treated at 1160°C



Treated at 1100°C

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12/10/9

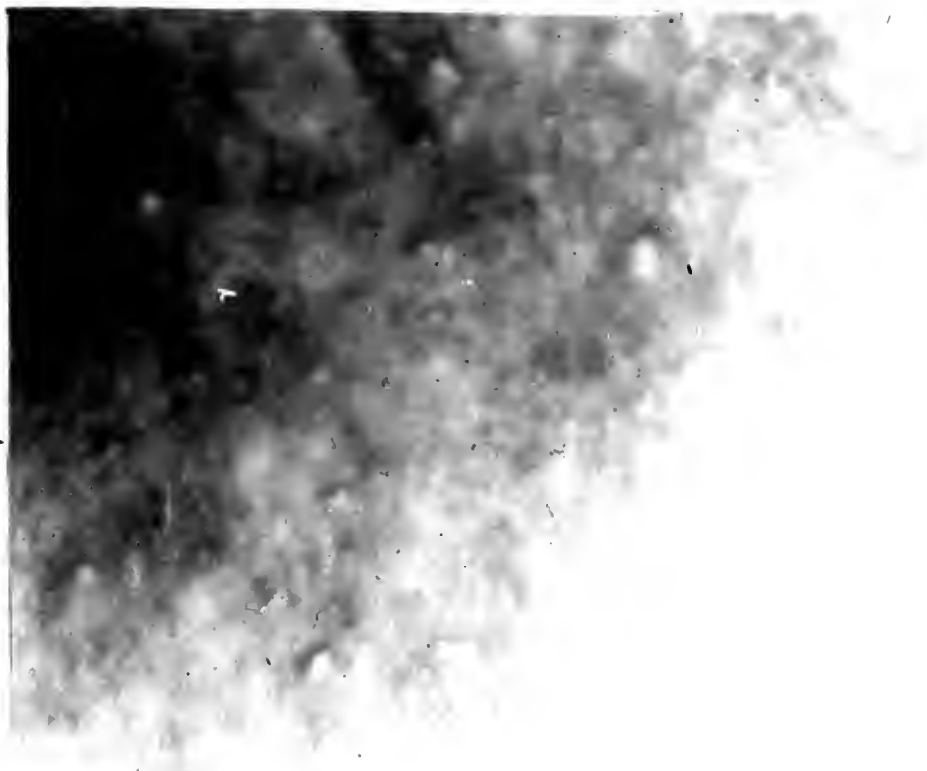
Treated at 1100°C

12/10/9

Poldi -- Treated at 1210°C



Poldi -- Treated at 1250°C



Travels of 1810

1811



Travels of 1811

1812

Arc

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Annealed



Arc

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Treated at 920°C



Belbenna

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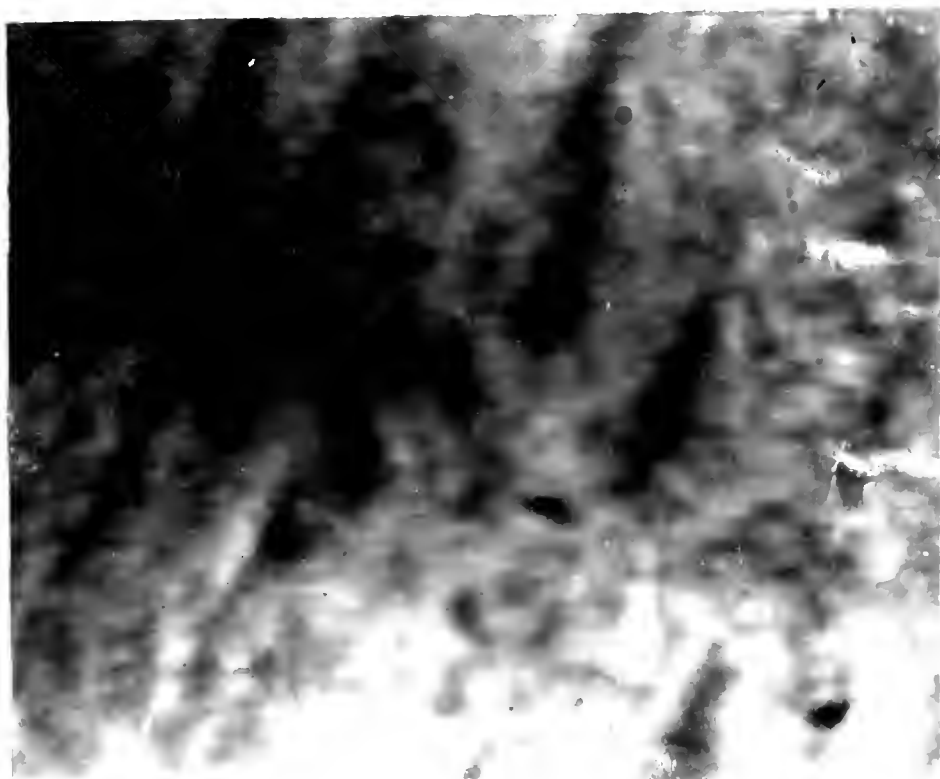
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Arc -- Treated at 980°c



Arc -- Treated at 1024°c



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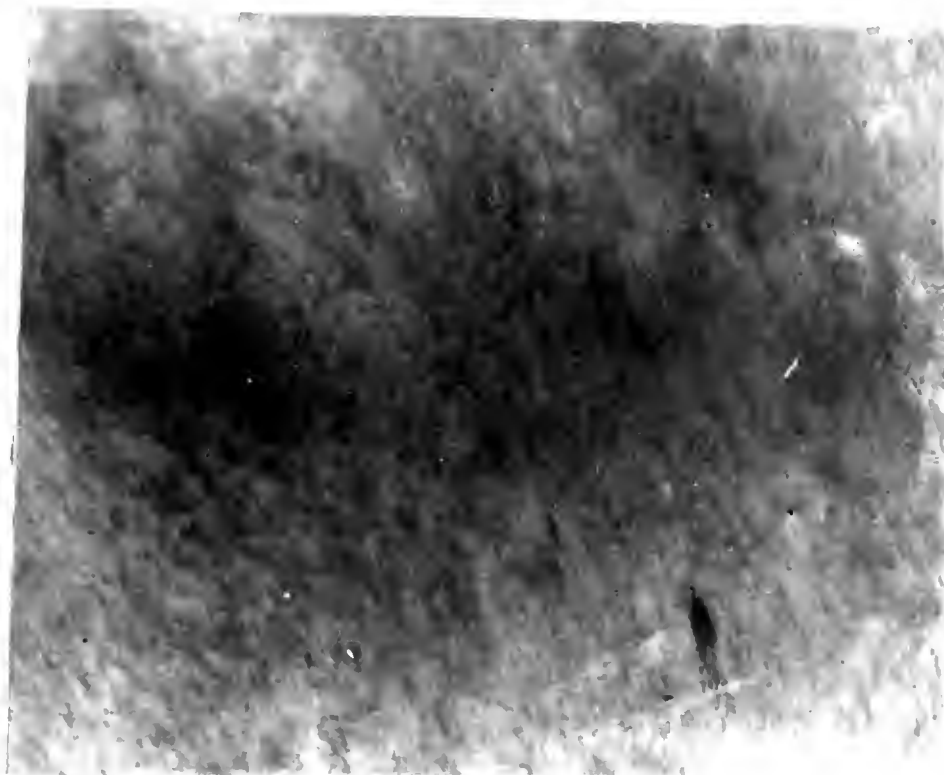
4. 20

974

Arc

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Treated at 1100°C



Arc

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Treated at 1160°C



000000 is betser

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ora

000000 is betser

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ora

Arc

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Treated at 1210°C



Arc

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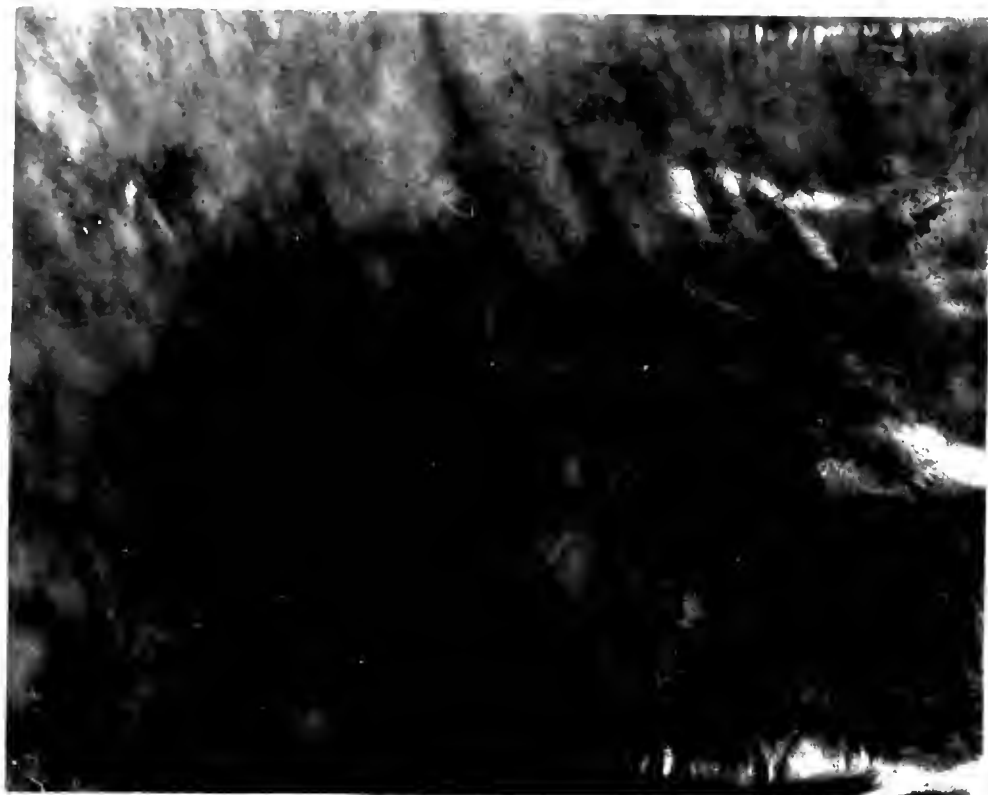
Treated at 1220°C



Bethlehem

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Annealed



Bethlehem

--

Treated at 900°C



1000000000

1000000000

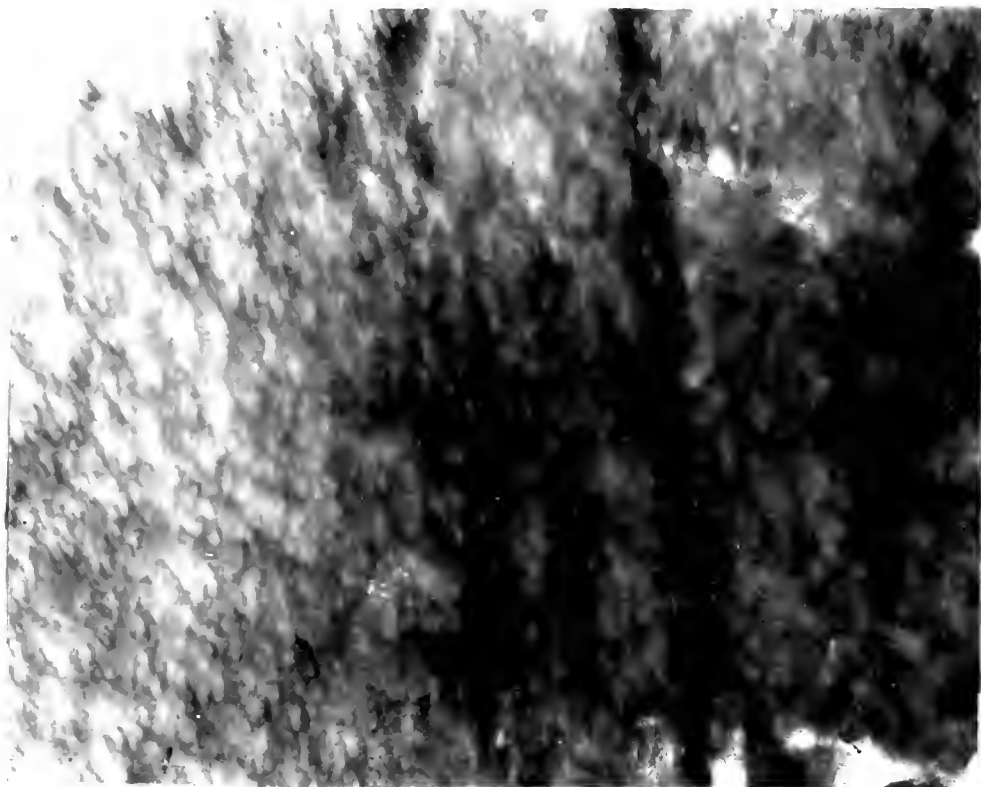
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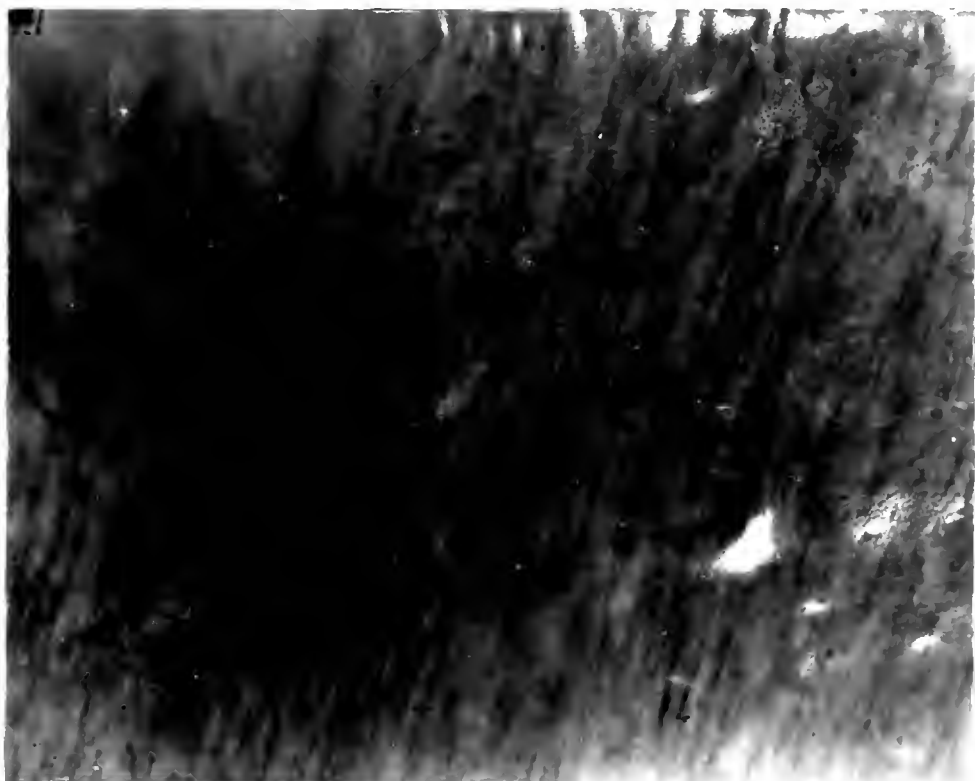
1000000000

1000000000

Bethlehem -- Treated at 980°C



Bethlehem -- Treated at 1040°C



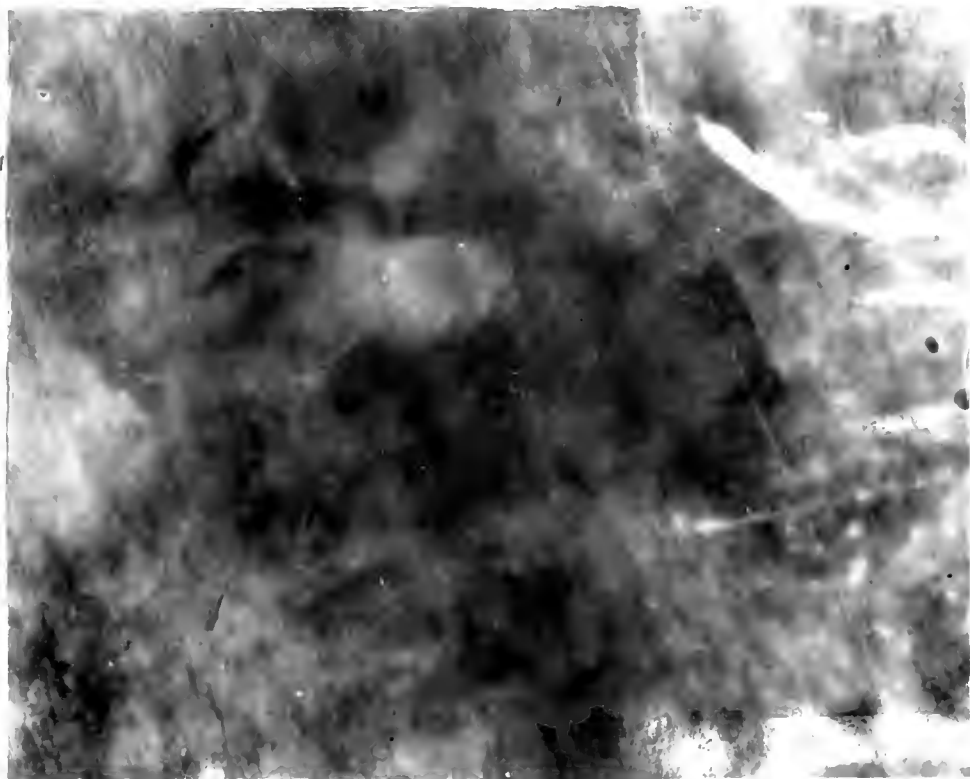
Testimony of the President of the United States

Testimony of the President of the United States

Bethlehem

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Treated at 1100°C



Bethlehem

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Treated at 1100°C



Journal des missions de la Compagnie des Indes

Journal des missions de la Compagnie des Indes

Bethlehem

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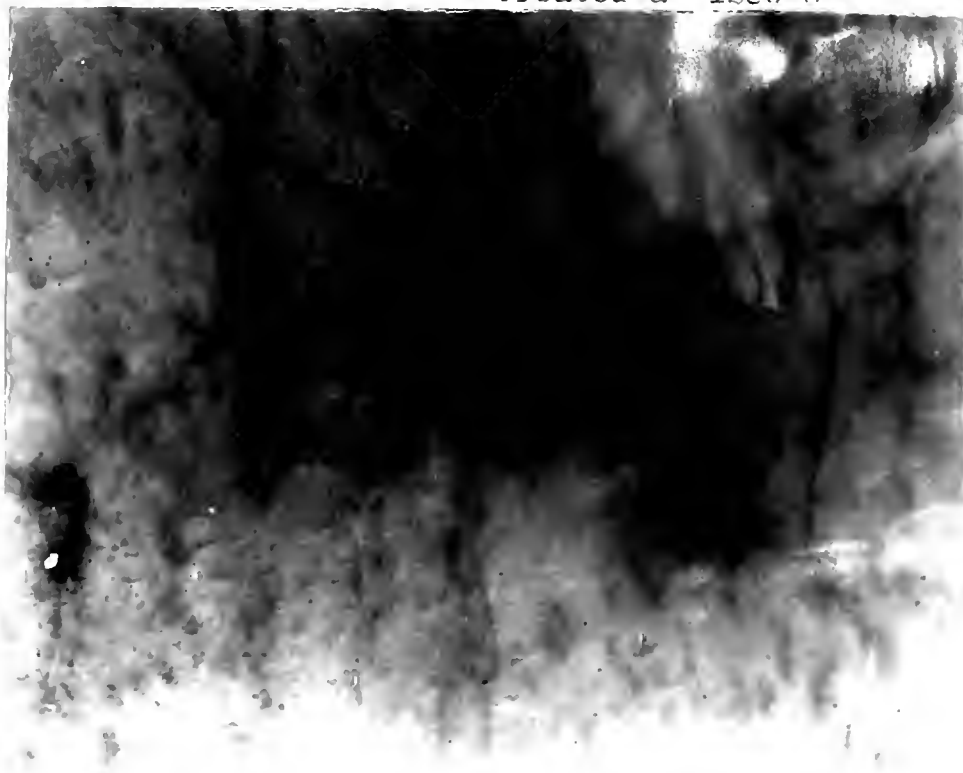
Treated at 1210°C



Bethlehem

--

Treated at 1280°C



U.S. v. Borden

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1811-1812

1

2

3

4

5

Novo -- Annealed



Novo -- Teated at 92000



Annals

1801

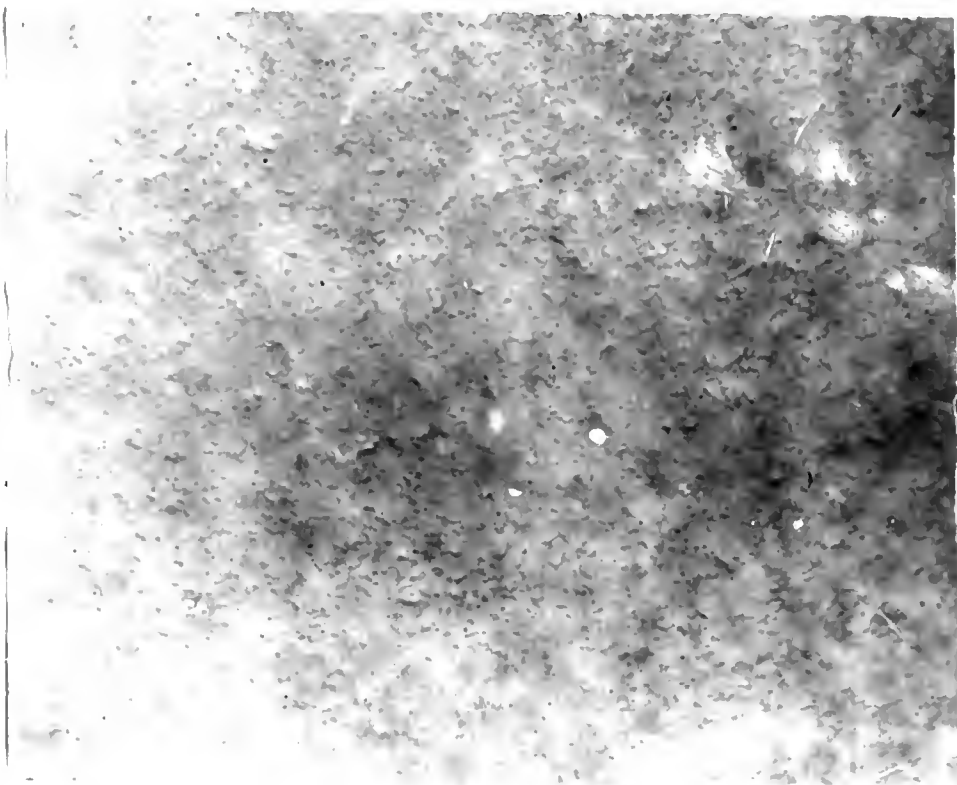
London

1801

Novo

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Treated at 980°C



Novo

--

Treated at 1040°C



30 139 42 221 67

OVOL

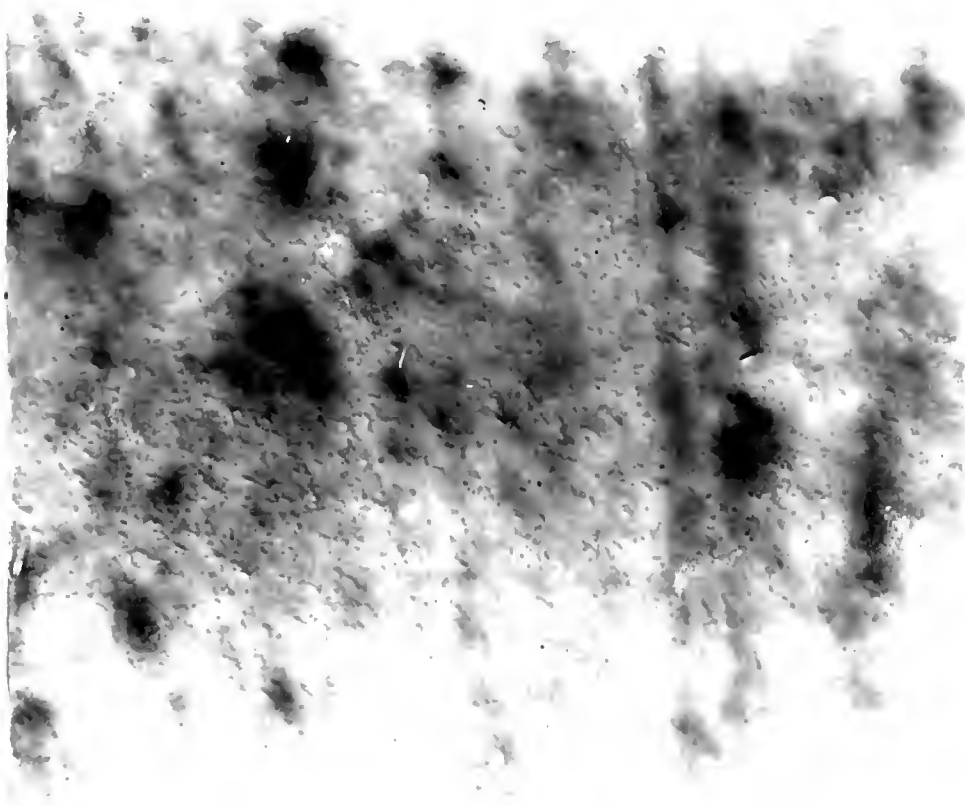
10 139 42 221 67

OVOL

Novo -- Treated at 1100°C



Novo -- Treated at 1160°C

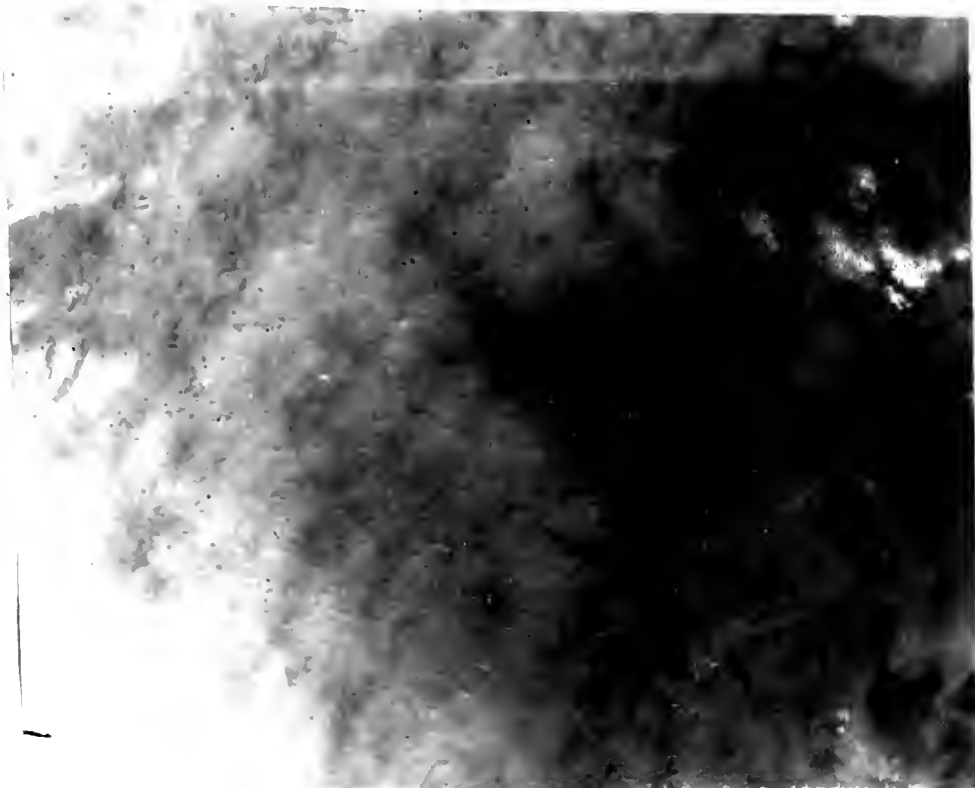


Y'all as before! ... over

Novo

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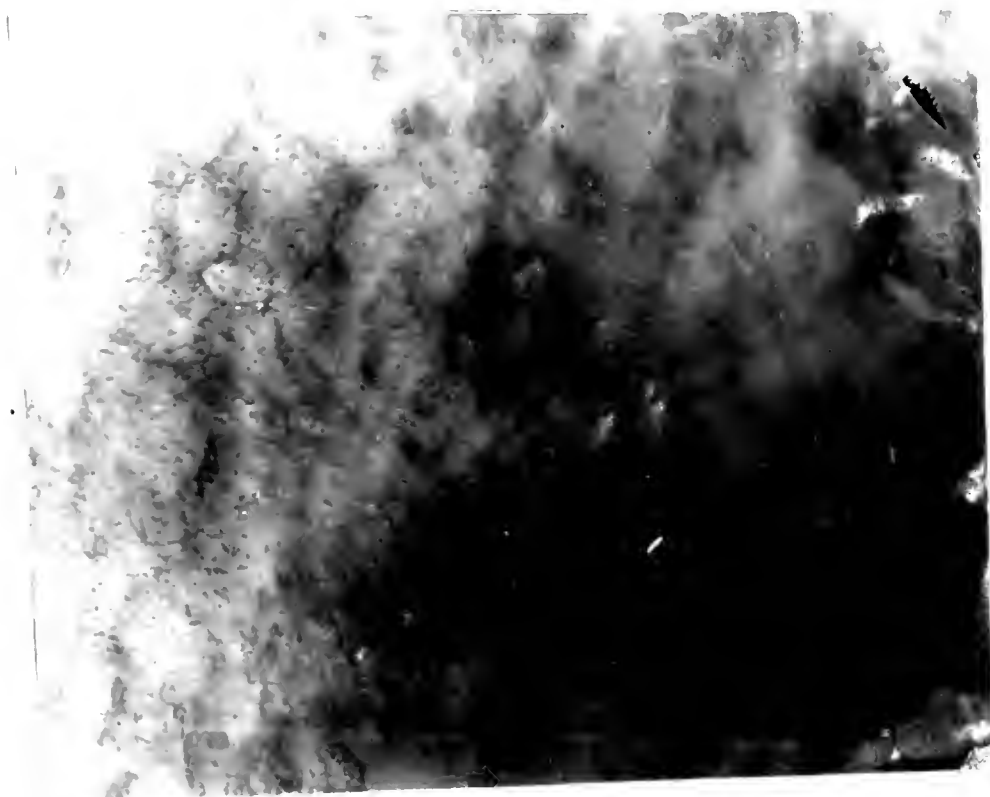
Treated at 1210°C



Novo

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Treated at 1280°C



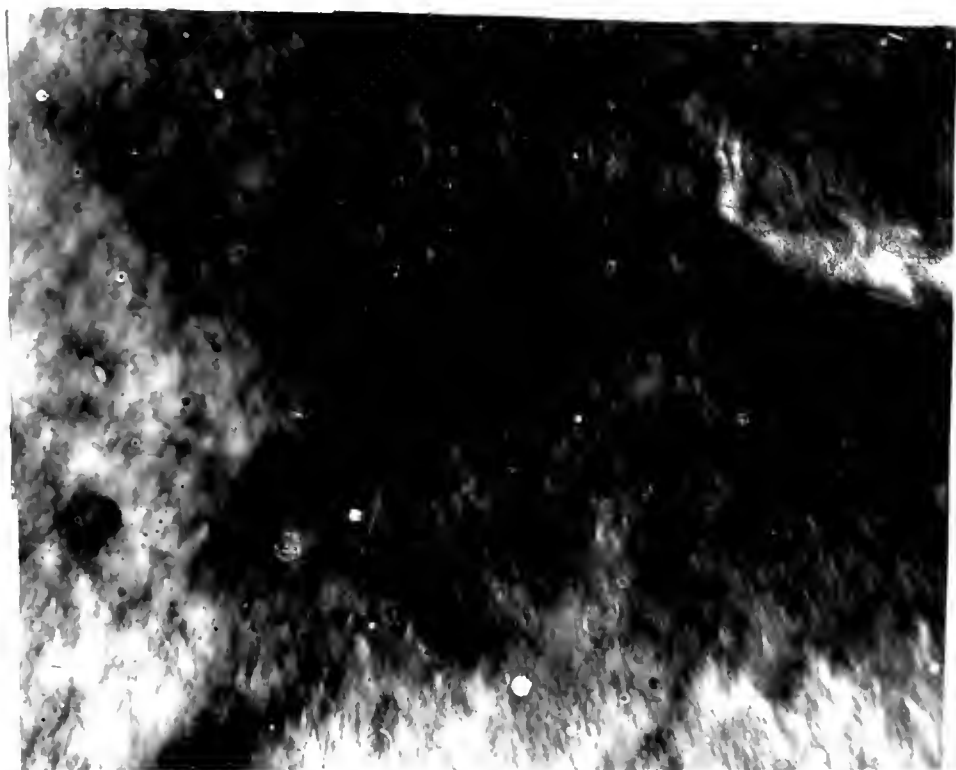
Ward's best effort — and

— — — — —

Rekord

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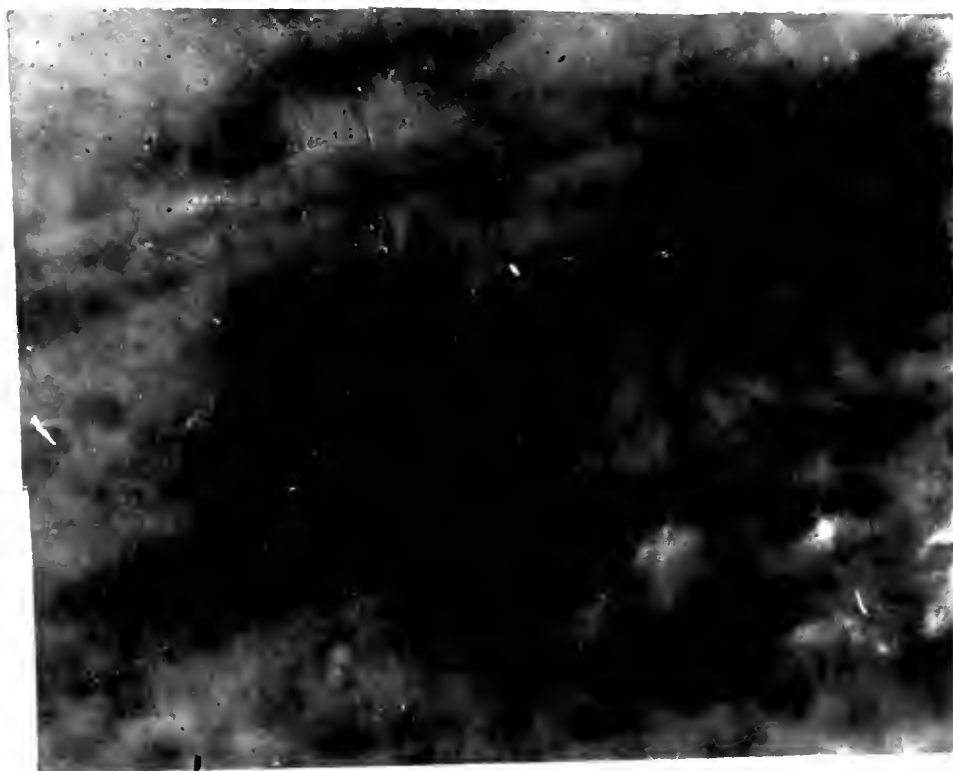
Annealed



Rekord

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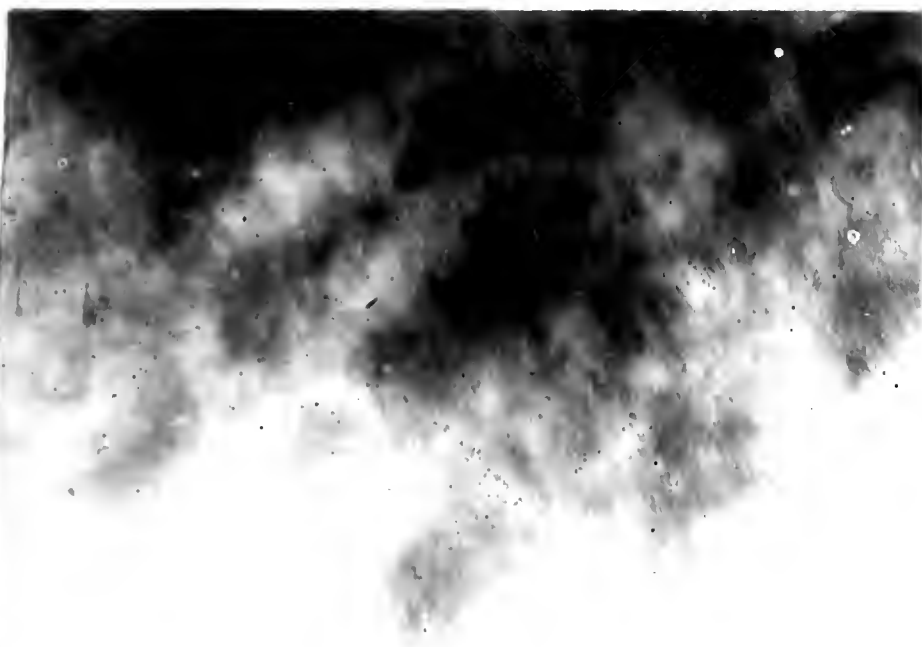
Treated at 920°C



Rekord

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Treated at 980°C



Rekord

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Treated at 1040°C



9030 4 187. 91.

100. 7

91

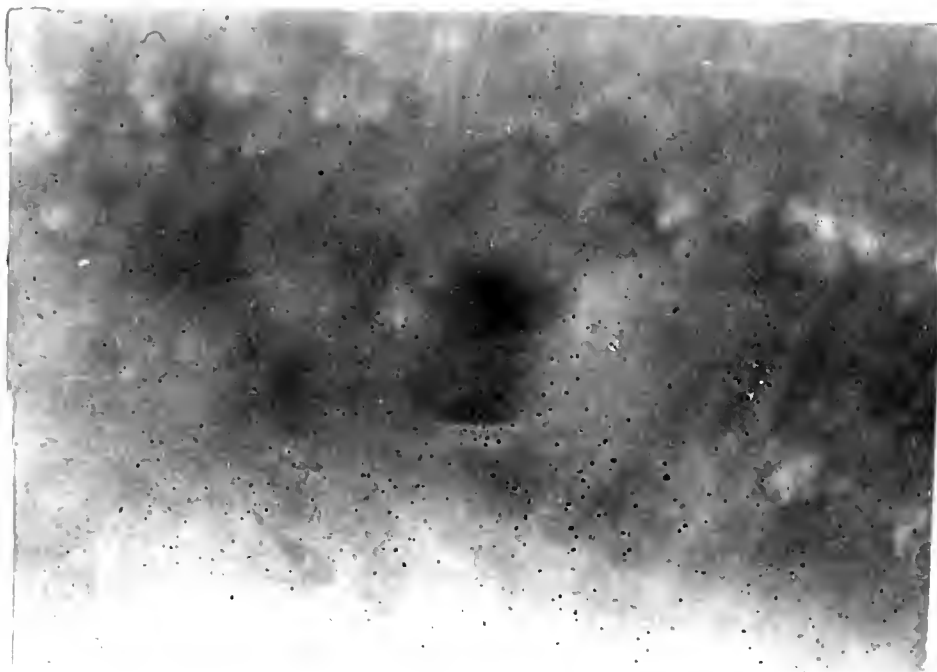
100. 7

100. 7

Rekprd

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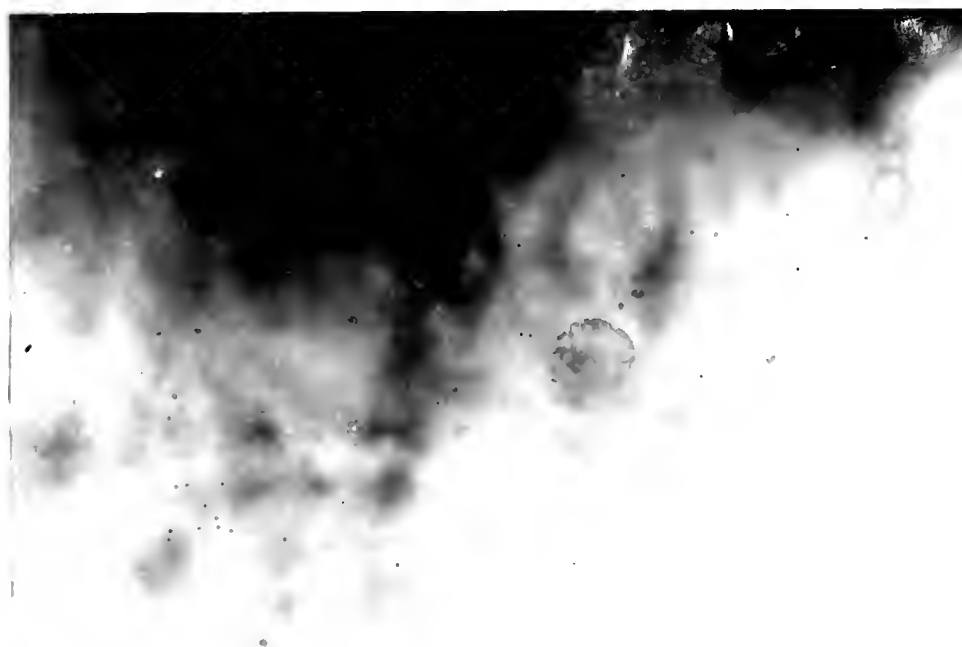
Treated at 1100°C



Rekord

--

Treated at 1160°C



Will it help?

— 276 —

6704-2

09-1-10-10-10

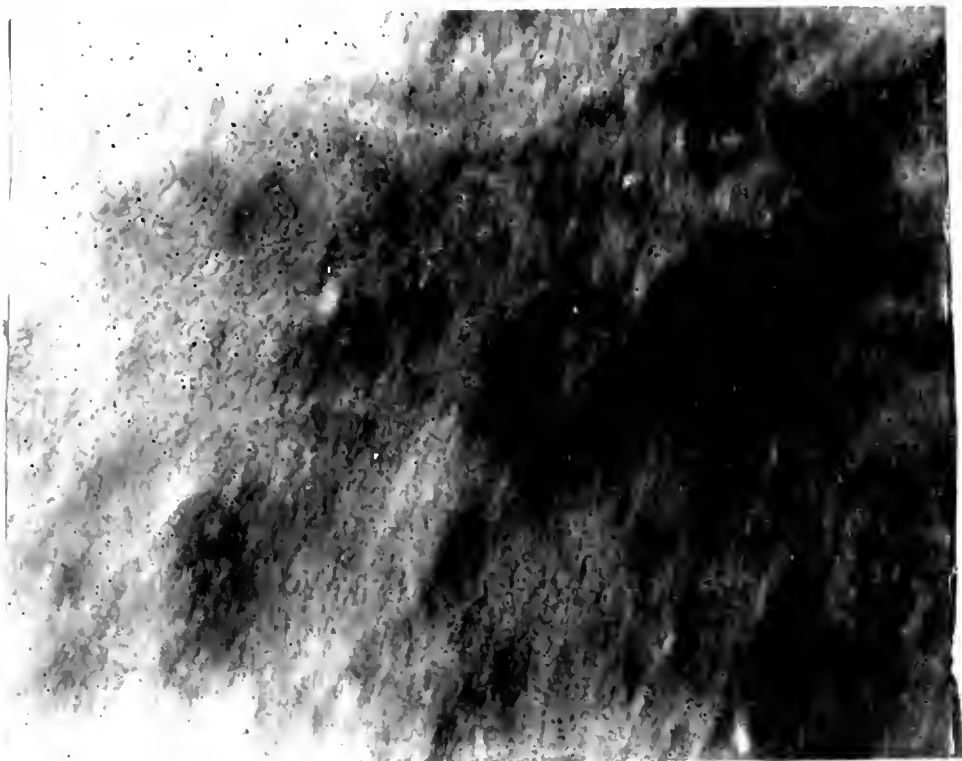
— 254 —

650208

Rekord

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Treated at 1210°C



Rekord

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Treated at 1280°C



10121 at 10121

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10121

10121 at 10121

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10121

Blue Chip

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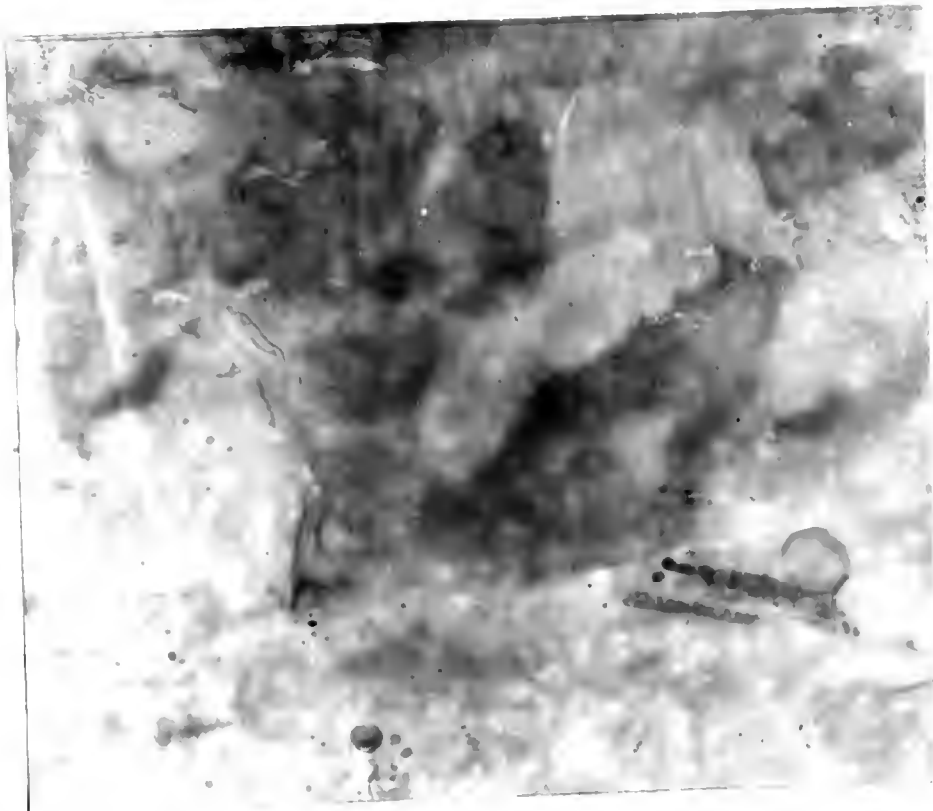
Annealed



Blue Chip

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Treated at 920°C



Unrevised

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Page 10 of 10

10/1/10 10:00 AM

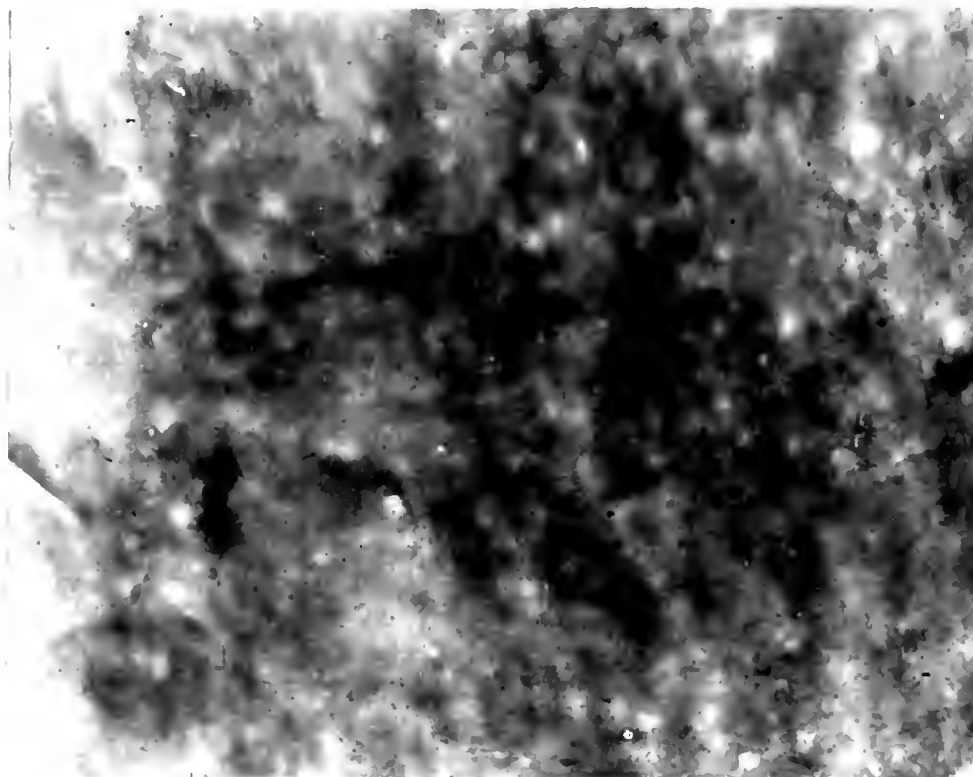
10

10/1/10 10:00 AM

Blue Chip

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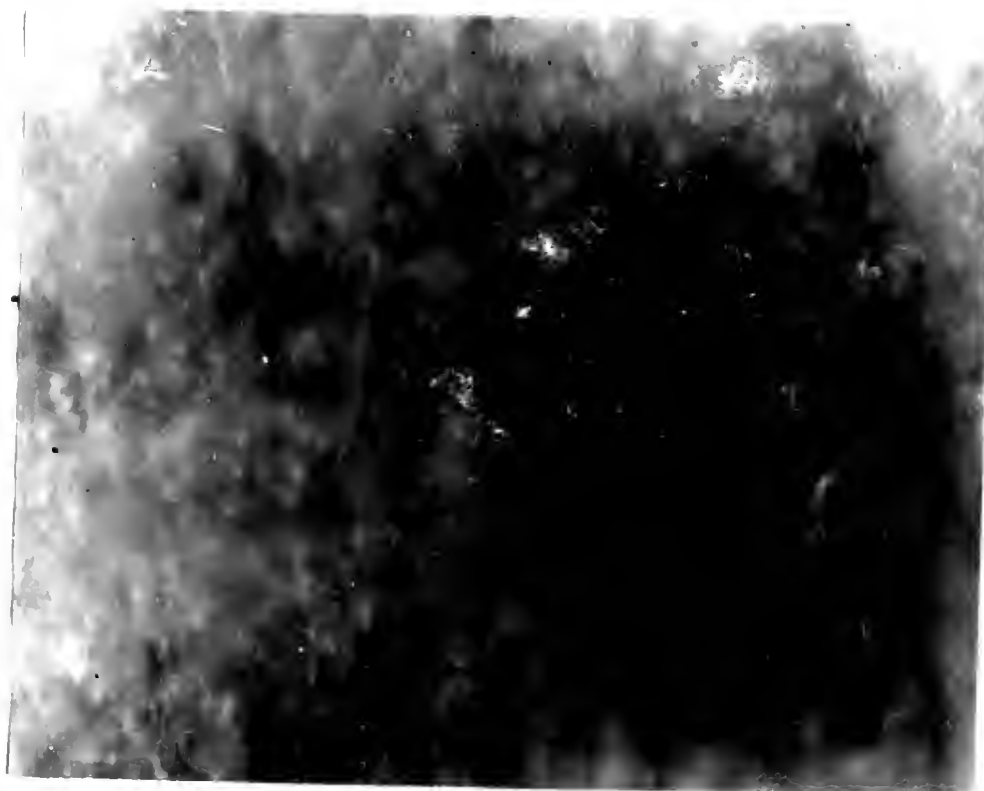
Treated at 980°C



Blue Chip

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Treated at 1040°C



Blue Chip

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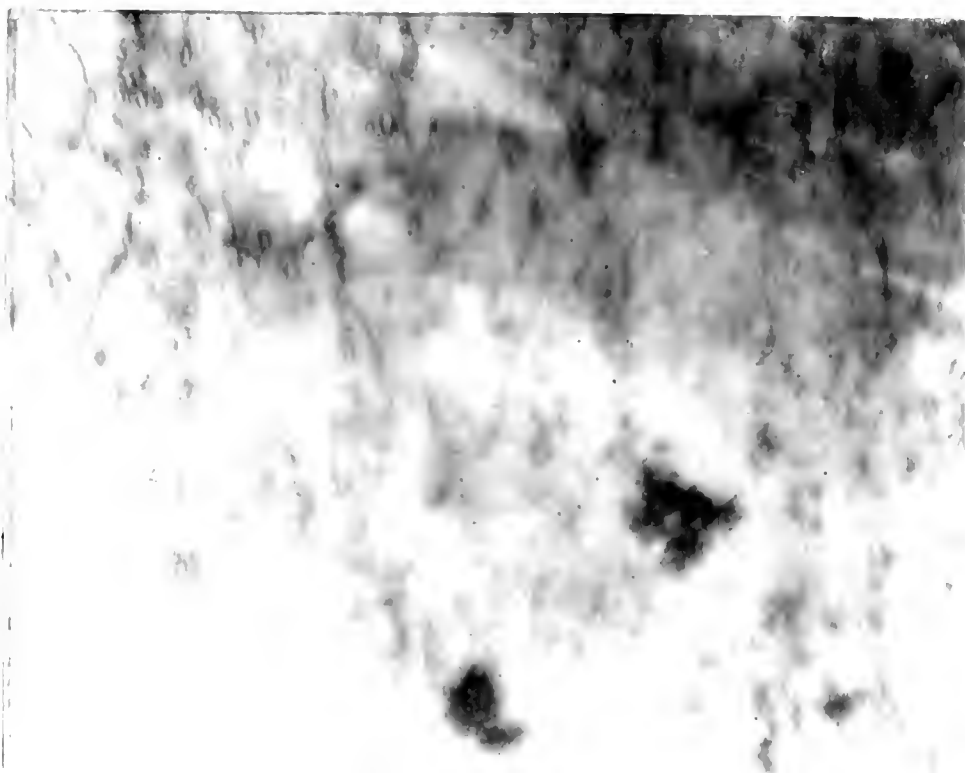
Treated at 1100°C



Blue Chip

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Treated at 1160°C



000011 to 000012

Blue Chip

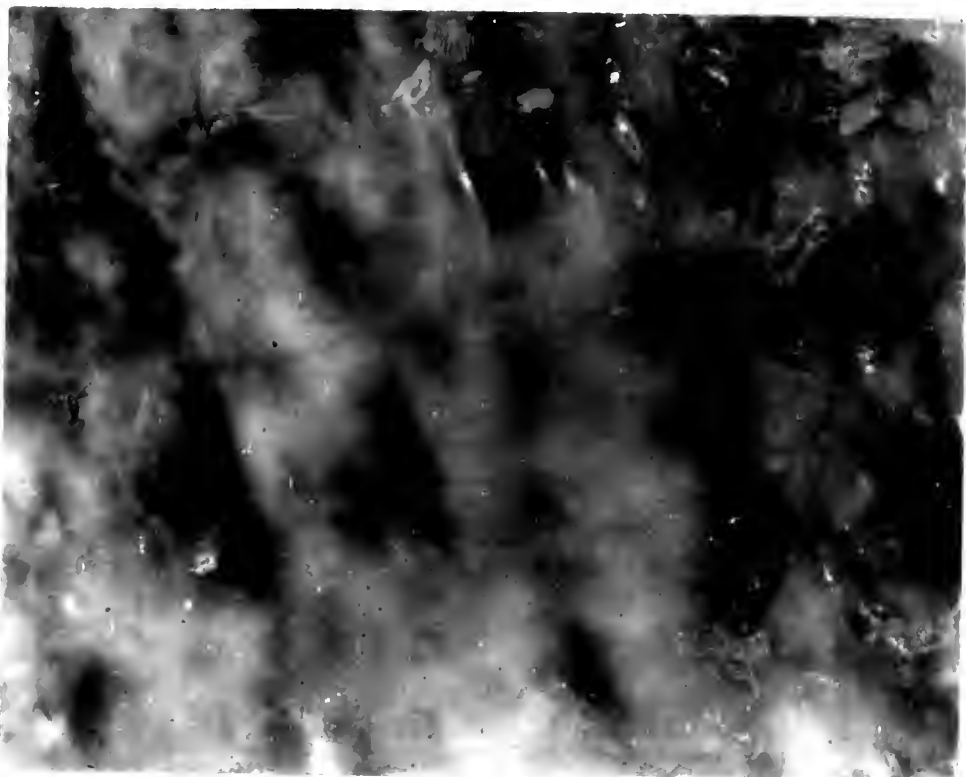
000011 to 000012

Blue Chip

Blue Chip

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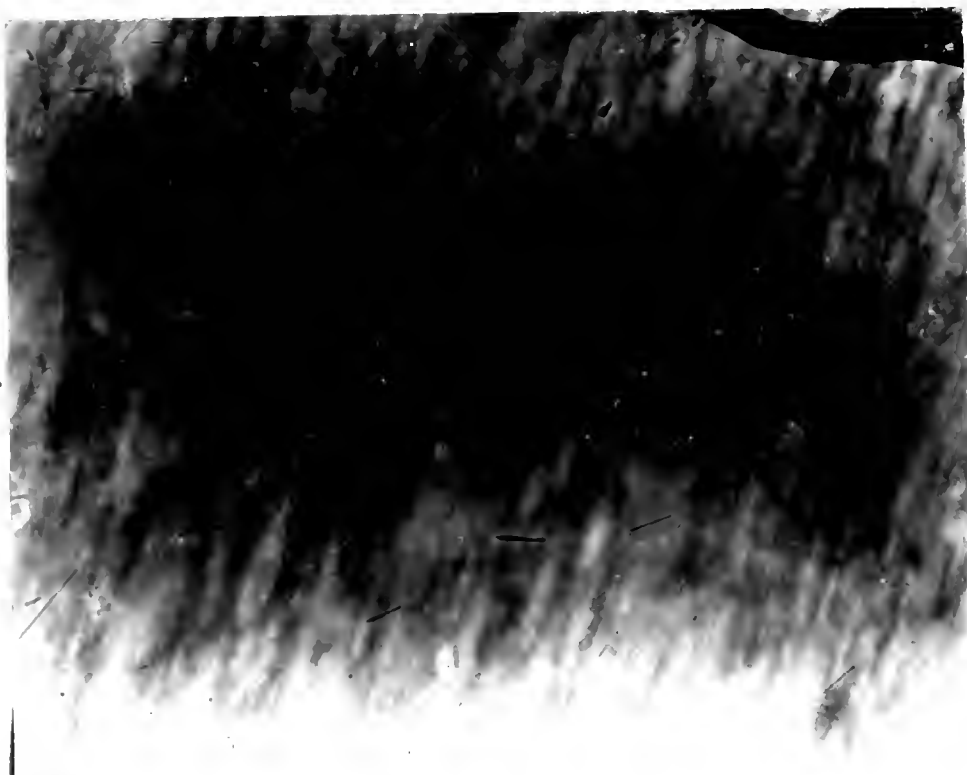
Treated at 1210°C



Blue Chip

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Treated at 1280°C



Blue Chip -- Printed at 191900

Blue Chip -- Printed at 191900

Interpretation of Results and Conclusions.

To give the best results as a cutting tool, high speed steel must possess, in addition to hardness, enough toughness and resilience to withstand a certain degree of shock. In the present case where the attempt is to determine toughness, or brittleness and hardness, from microphotographs showing the structure of the steel, established standards are necessary to permit definite statements. On carbon steels and irons, enough work has been done to make it possible to pass accurate judgment on a specimen by obtaining a good microphotograph of it. In the case of the chrome tungsten steels, this does not hold true. Work has been done but it is not sufficient.

The prints on the preceding pages can be commented on only by inference from what is known definitely regarding such materials as carbon steels and from a small amount of direct knowledge concerning high speed steel.

It is probable that in the high speed steels as elsewhere, coarse structure is an indication of a tendency toward brittleness. This is borne out by the observation that those specimens showing particularly coarse structures broke readily under the hammer. Conversely, it is probably true that fine homogenous structures indicate that the specimen will stand shock. Also a marked cellular structure in a chrome tungsten steel is interpreted as indicating the presence of a double

APR 11 1968

1. The first of these is the fact that the
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11. Government has been unable to secure the
12. necessary funds to carry out its policy.

carbide of tungsten which lends hardness to the specimen.

Referring to the microphotographic prints of Roldi, it is seen that the annealed specimen shows fairly large crystals, in a striated and rather non-homogenous field. At 920 degrees, this original structure has broken up, resulting in smaller crystals set in a fairly homogenous field. From 920 degrees to 1040 degrees, there seems to be a steady growth in the size of the crystals and an increase in the degree of separation between them - the compound crystals are segregated more distinctly from the ferrite matrix. At 1100 degrees a banded homogenous structure rather coarse crystalline, appears and at 1160 degrees the band markings have almost disappeared, the crystals have grown smaller and cellular grains appear. At 1210 degrees, grain markings are disappearing and the crystals have elongated, while at 1280 degrees, a coarse non-homogenous structure appears.

Between 1100 degrees and 1160 degrees we pass from a typically banded structure to a homogenous close cellular grain structure. On the assumption that the cellular structure indicates hardness (see above) the best temperature for this steel may be supposed to be between 1100 and 1160 degrees, the cells having grown somewhat larger than is supposed desirable at the latter temperature.

The annealed specimen of Arc shows a non-homogenous field of moderate sized crystals, and a striated

structure, which has not completely broken up at 920 degrees, though the crystals have decreased in size. At 980 degrees a rearrangement into coarser crystals appears, showing non-homogenous areas and a remnant of the striated structure. At 1040 degrees, smaller crystals appear in a more homogenous field and at 1100 degrees the field is quite homogenous. At 1160 degrees large cellular grains are marked in a still homogenous field from which crystalline structure has largely disappeared. A rearrangement is noted at 1210 degrees, resulting in a field showing non-homogenous areas and a loss of the cellular markings, which appear once more as the outline of large sized grains in an extremely non-homogenous field at 1280 degrees.

From the trend of this series of prints, it seems likely that at slightly above 1100 degrees, a structure possessing the characteristics of homogeneity with fine crystalline structure and yet marked by close cellular grains would be obtained. The best temperature, in this case, seems therefore, in that vicinity.

Bethlehem seems to lose the banded structure of the annealed specimen when treated at 920 degrees, but retains the original non-homogeneity and shows large crystals. At 980 degrees, the crystals are rearranged and segregated to sharper separation from the ferrite matrix and a return to the banded structure is

noted, and at 1040 degrees the crystals have elongated and grown in size, but the field is fairly uniform. From 1040 to 1210, a progressive decrease in the size of the crystals is noted with the result that at 1210 degrees, we have a very fine homogenous crystalline structure. At 1280 degrees, a coarse cellular structure is plainly shown - probably indicating a very hard, yet brittle specimen.

The fine homogenous field at 1210 degrees and the large grains at 1280 degrees lead to the opinion that slightly above 1210 degrees may be designated as the temperature that would produce the best results with Bethlehem.

The slightly banded non-homogenous field shown by annealed iron does not show complete rearrangement until 980 degrees is reached. Here we have moderate sized crystals in a homogenous field. At 1040 degrees there is noted a second complete rearrangement resulting in an unique field showing non-homogenous areas containing coarse crystals markedly segregated. At 1100 degrees, the field is homogenous and contains moderate sized crystals, while at 1160 degrees, it is again non-homogenous and shows segregation, though the structure is not so coarse as at 1040 degrees. 1210 degrees presents a fairly homogenous field with smaller structure supposed to indicate hardness. The photographs here are not particularly decisive. Probably a point between 1210 degrees and 1280 degrees could be designated as the

best temperature, but 1100 degrees also shows a good structure.

The annealed specimen of rekord shows fairly large crystals in a rather homogenous field. 920 degrees brings a rearrangement resulting in a field containing non-homogenous areas, which feature persists at 980 degrees, though the crystals are fairly small here. At 1040 degrees the field is more homogenous but shows fairly marked segregation and large crystals, which, at 1100 degrees have become small and are close set into a homogenous structure. As far as can be judged from the print the structure at 1160 degrees resembles that at 1100 degrees. At 1210 degrees there is a coarse field with non-homogenous areas which features are more emphasized at 1280 degrees.

It is remarked that none of the prints of this series shows distinct granular structure. The best structures seem to occur at 1100 to 1160 degrees.

Heating to 920 degrees changes the banded structure of annealed Blue Chip to a homogenous structure of fairly large crystals distributed through a matrix. From 920 degrees to 1040 degrees the most noticeable change is a loss of homogeneity. From what can be learned from the print there is no marked segregation at 1100 degrees but at 1160 degrees large cellular grains appear and the segregation has occurred with a loss of homogeneity. At 1210 degrees the cellular markings are not seen, but at

1280 degrees there is a slight reappearance of these markings.

Some desirable characteristics, as judged from the photos, appear when Blue Chip is heated to 1100 degrees, while it is apparently hard at 1160 degrees, the best temperature probably lying between these two points.

While sufficient work has not been done to permit of any definite statements, it is noticed that a change of 60 degrees C. is the temperature to which a chrome tungsten high speed is heated prior to quenching results in a marked structure change, in most cases. It would seem, therefore, that careful investigation should reveal a temperature, unique for each steel, that should be closely adhered to, to obtain the best results. It seems worth while to prove or disprove, by careful study, the idea that a temperature for heating prior to quenching can be found which will give much better results than a temperature only slightly above or below.

It is believed by the authors that definite conclusions could be arrived at by studying a large number of specimens by making a number of physical tests - tensile, transverse, cutting and hardness - together with the taking of microphotographs. In this way, sufficient general knowledge might be acquired to enable passing accurate judgment on other specimens solely by examining the microphotographs. The indications obtained in the work done, show distinct possibilities of

obtaining good results from a careful, thorough and lengthy investigation of the problem.

It will be noted that there is an indication that the best temperature for heat treating is highest in the steels containing the largest per cent of tungsten. This may or may not be coincidence.





